

**TESTIMONY OF**  
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**DEPARTMENT OF COMMERCE**  
  
**BEFORE THE**  
**COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION**  
**UNITED STATES SENATE**

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Mr. Chairman:

I am a Senior Scientist at NOAA's Geophysical Fluid Dynamics Laboratory located in Princeton University, Princeton, New Jersey. I appreciate the invitation to appear before your Committee and report on the state of the scientific understanding of global climate change as documented in the recently concluded Intergovernmental Panel on Climate Change (IPCC) assessment ["Climate Change 2001: The Scientific Basis"]. The IPCC was set up by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to provide expert assessment of the knowledge and an authoritative international statement of the scientific understanding on climate change.

For over 30 years, the Geophysical Fluid Dynamics Laboratory has been a world leader in the development of numerical models for studying climate variations and climate change, and has made major contributions to the understanding of the Earth's climate system. My own research has involved estimating the natural and human-induced factors that force climate change, as well as investigating the manner in which the climate system responds to these factors. For over a decade, I have been involved in various national and international scientific assessments. These include National Academy of Science studies, WMO/ UNEP reports on the scientific understanding of the ozone layer and IPCC climate change science assessments. In the recently concluded IPCC scientific assignment, I served as the Coordinating Lead Author for the Chapter on "Radiative Forcing of Climate Change." I was also a member of the panel which drafted the Summary for Policymakers that was formally approved in detail and accepted along with the underlying assessment report at the IPCC Working Group I Plenary session in January 2001. [Copies of the Summary for PolicyMakers and Technical Summary will be made available to the Committee on the day of the hearing].

I appreciate the invitation to summarize the findings from the IPCC (2001) report. My information is based on the set of findings in this report. The assessment took almost three years in preparation and represents the work of over a hundred scientific authors worldwide. It is based on scientific literature, and was carefully scrutinized by hundreds of scientific peers through an extensive peer review process. My testimony today summarizes the understanding of these authors as manifested in the report.

Before addressing the new findings of the recent report, two fundamental points are worthy of note. These have been long-known, are very well understood, and have been deeply underscored in all previous IPCC reports and other such scientific summaries.

*\* The "greenhouse" effect is real, and is an essential component of the planet's climate process.* A small percentage (roughly 2%) of the atmosphere is, and long has been, composed of greenhouse gases (water vapor, carbon dioxide, ozone and methane). These effectively prevent part of the heat radiated by the Earth's surface from otherwise escaping to space. The global system responds to this trapped heat with a climate that is warmer, on the average, than it would be otherwise without the presence of these gases.

In addition to the natural greenhouse effect above, there is a change underway in the greenhouse radiation balance, namely:

*\* Some greenhouse gases are increasing in the atmosphere because of human activities and increasingly trapping more heat.* Direct atmospheric measurements made over the past 40-plus years have documented the steady growth in the atmospheric abundance of carbon dioxide. In addition to these direct real-time measurements, ice cores have revealed the atmospheric carbon dioxide concentrations of the distant past. Measurements using the air bubbles that were trapped within the layers of accumulating snow show that atmospheric carbon dioxide has increased by more than 30% over the Industrial Era (since 1750), compared to the relatively constant abundance that it had over the preceding 750 years of the past millennium [see Figure 2, IPCC Working Group I Summary for Policymakers, page 6]. The predominant cause of this increase in carbon dioxide is the combustion of fossil fuels and the burning of forests. Further, methane abundance has doubled over the Industrial Era. Other heat-trapping gases are also increasing as a result of human activities.

The increase in greenhouse gas concentrations in the atmosphere implies a positive radiative forcing, i.e., a tendency to warm the climate system [see Figure 3, IPCC Working Group I Summary for Policymakers, 2001; page 8]. Particles (or aerosols) in the atmosphere resulting from human activities can also affect climate. Aerosols vary considerably by region. Some aerosol types act in a sense opposite to the greenhouse gases and cause a negative forcing or cooling of the climate system (e.g., sulfate aerosol), while others act in the same sense and warm the climate (e.g., soot). In contrast to the long-lived nature of carbon dioxide (centuries), aerosols are short-lived and removed from the lower atmosphere relatively quickly (within a few days). Therefore, aerosols exert a long-term forcing on climate only because their emissions

continue each year. In summary, emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that are expected to affect the climate. There are also natural factors which exert a forcing of climate, e.g., changes in the Sun's energy output and short-lived (about 1 to 2 years) aerosols in the stratosphere following episodic and explosive volcanic eruptions. IPCC evaluated the state of the knowledge and assessed the level of scientific understanding of each forcing. The level of understanding and the forcing estimate in the case of the greenhouse gases are greater than for other forcing agents.

What do these changes in the forcing agents mean for changes in the climate system? What climate changes have been observed? How well are the causes of those changes understood? Namely, what are changes due to natural factors, and what are changes due to the greenhouse-gas increases? And, what does this understanding potentially imply about the climate of the future?

These questions bear directly on the scientific points that you have asked me to address today. In doing so, findings emerging from the recent IPCC climate science report with respect to measurements, analyses of climate change to date, and projections of climate change will be summarized.

*\* There is a growing set of observations that yields a collective picture of a warming world over the past century.* The global-average surface temperature has increased over the 20th century by 0.7 to 1.4 degrees Fahrenheit [See Figure 1, IPCC Working Group I Summary for Policymakers, 2001, page 3]. The average temperature increase in the Northern Hemisphere over the 20th century is likely to have been the largest of any century during the past 1,000 years, based on "proxy" data (and their uncertainties) from tree rings, corals, ice cores, and historical records. Other observed changes are consistent with this warming. There has been a widespread retreat of mountain glaciers in non-polar regions. Snow cover and ice extent have decreased. The global-average sea level has risen between 4 and 8 inches, which is consistent with a warmer ocean occupying more space because of the thermal expansion of sea water and loss of land ice.

*\* There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.* The 1995 IPCC climate-science assessment report concluded: "The balance of evidence suggests a discernible human influence on global climate." There is now a longer and more closely scrutinized observed temperature record. Climate models have evolved and improved significantly since the last assessment. Although many of the sources of uncertainty identified in 1995 still remain to some degree, new evidence and improved understanding support the updated conclusion. Namely, recent analyses have compared the surface temperatures measured over the last 140 years to those simulated by mathematical models of the climate system, thereby evaluating the degree to which human influences can be detected. Both natural climate-change agents (solar variation and episodic, explosive volcanic eruptions) and human-related agents (greenhouse gases and fine particles) were included. The natural climate-change agents alone do not explain the warming in the second half of the 20th century. The best agreement between observations and model simulations over the last 140 years is found when both human-related and natural climate-change agents are included in

the simulations [see Figure 4, IPCC Working Group I Summary for Policymakers, 2001; page 11]. Further, model simulations indicate that the warming over the past century is very unlikely to be due to internal variability alone, i.e., variations within the climate system that would be expected even in the absence of any forcing. In light of such new evidence and taking into account the remaining uncertainties, the IPCC scientists concluded that most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations.

*\* Scenarios of future human activities indicate continued changes in atmospheric composition throughout the 21st century.* The atmospheric abundances of greenhouse gases and aerosols over the next 100 years cannot be predicted with high confidence, since the future emissions of these species will depend on many diverse factors, e.g., world population, economies, technologies, and human choices, which are not uniquely specifiable. Rather, the IPCC assessment endeavor aimed at establishing a set of scenarios of greenhouse gas and aerosol abundances, with each based on a picture of what the world plausibly could be over the 21st century. [The emission scenarios were based on the IPCC Special Report on Emissions Scenarios, 2000; a brief description of the scenarios appears in the box on page 18 of the Summary for Policymakers report.] Based on these scenarios and the estimated uncertainties in climate models, the resulting projection for the global average temperature increase by the year 2100 ranges from 2.5 to 10 degrees Fahrenheit [see Figure 5, IPCC Working Group I Summary for Policymakers, 2001; page 14]. Such a projected rate of warming would be much larger than the observed 20th-century changes and would very likely be without precedent during at least the last 10,000 years. The corresponding projected increase in global sea level by the end of this century ranges from 3.5 to 35 inches. Uncertainties in the understanding of some climate processes make it more difficult to project meaningfully the corresponding changes in regional climate.

Finally, I would like to relate a basic scientific aspect, one that has been underscored with very high confidence in all of the IPCC climate-science assessment reports (1990, 1995, and 2001). It is repeated here because it is a key (perhaps "the" key) aspect of a greenhouse-gas-induced climate change:

*\* A greenhouse-gas warming could be reversed only very slowly.* This quasi-irreversibility arises because of the slow rate of removal (centuries) from the atmosphere of many of the greenhouse gases and because of the slow response of the oceans to thermal changes. For example, several centuries after carbon dioxide emissions occur, about a quarter of the increase in the atmospheric concentrations caused by these emissions is projected to still be in the atmosphere. Additionally, global average temperature increases and rising sea level are projected to continue for hundreds of years after a stabilization of greenhouse gas concentrations (including a stabilization at today's abundances), owing to the long timescales (centuries) on which the deep ocean adjusts to climate change.

Let me conclude, Mr. Chairman, with an important remark concerning the IPCC report. As noted, the IPCC climate-science assessment is the considered viewpoint of hundreds of scientists worldwide. This assessment is based upon the research results of the worldwide community that are published in

numerous peer-reviewed scientific journals. The resulting report contains policy-relevant scientific information, but makes no policy statements or recommendations. As such, the three components of the 2001 IPCC Third Assessment Report - climate science, impacts, and mitigation - are recommended as a key information source that is available to the Committee as it continues this important dialogue about climate change and its relation to humankind.

Thank you for the invitation to appear today. I hope that this summary has been useful. I would be happy to address any questions.

**Source of cited information:**

Summary for Policy Makers, Climate Change 2001: The Scientific Basis. Summary for Policymakers and Technical Summary of the Working Group I Report. Cambridge University Press, 98pp. Also available at <http://www.ipcc.ch>.  
The full report will be available this summer.

Parallel IPCC reports:

Climate Change 2001: Impacts, Adaptation and Vulnerability - Contribution of Working Group II to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.

Climate Change 2001: Mitigation - Contribution of Working Group III to the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.

IPCC, 2000: IPCC Special Report on Emissions Scenarios. Cambridge University Press.